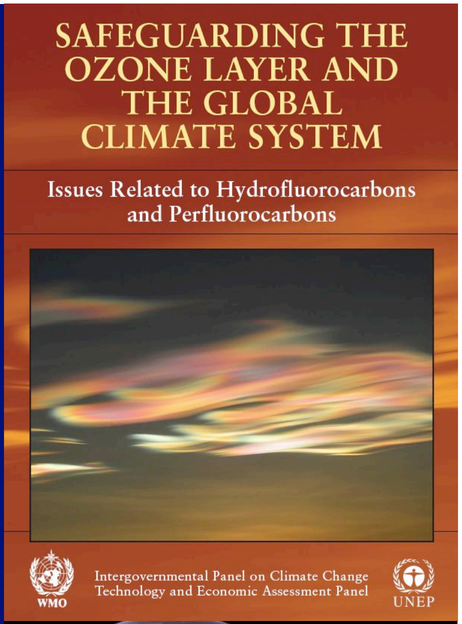
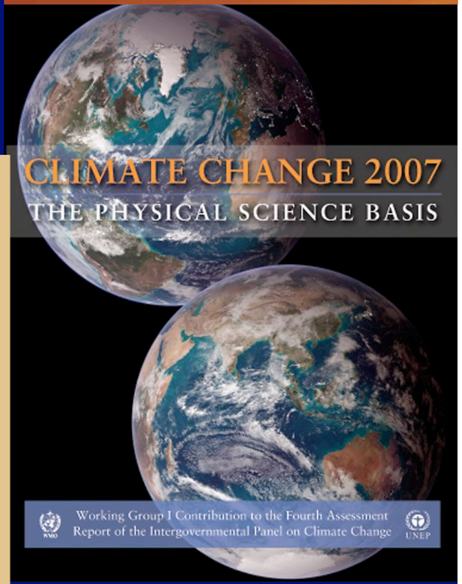
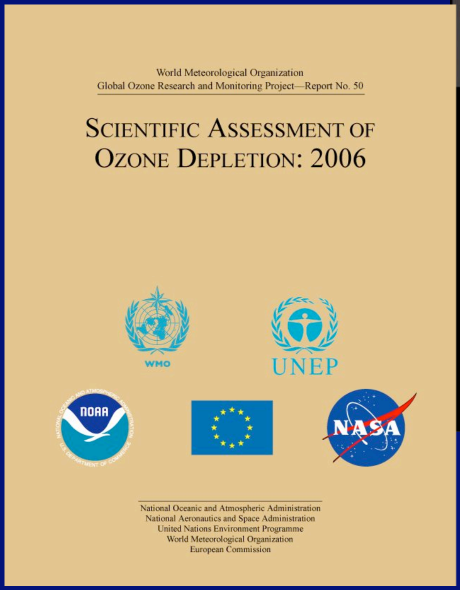
Some Highlights of NOAA Contributions to Assessments

Susan Solomon

1. Introduction and Background: what is assessment, and what is successful assessment?
2. WMO/UNEP Ozone Assessments
3. IPCC Special Report and WG1 AR4
4. Summary and Outlook for the Future



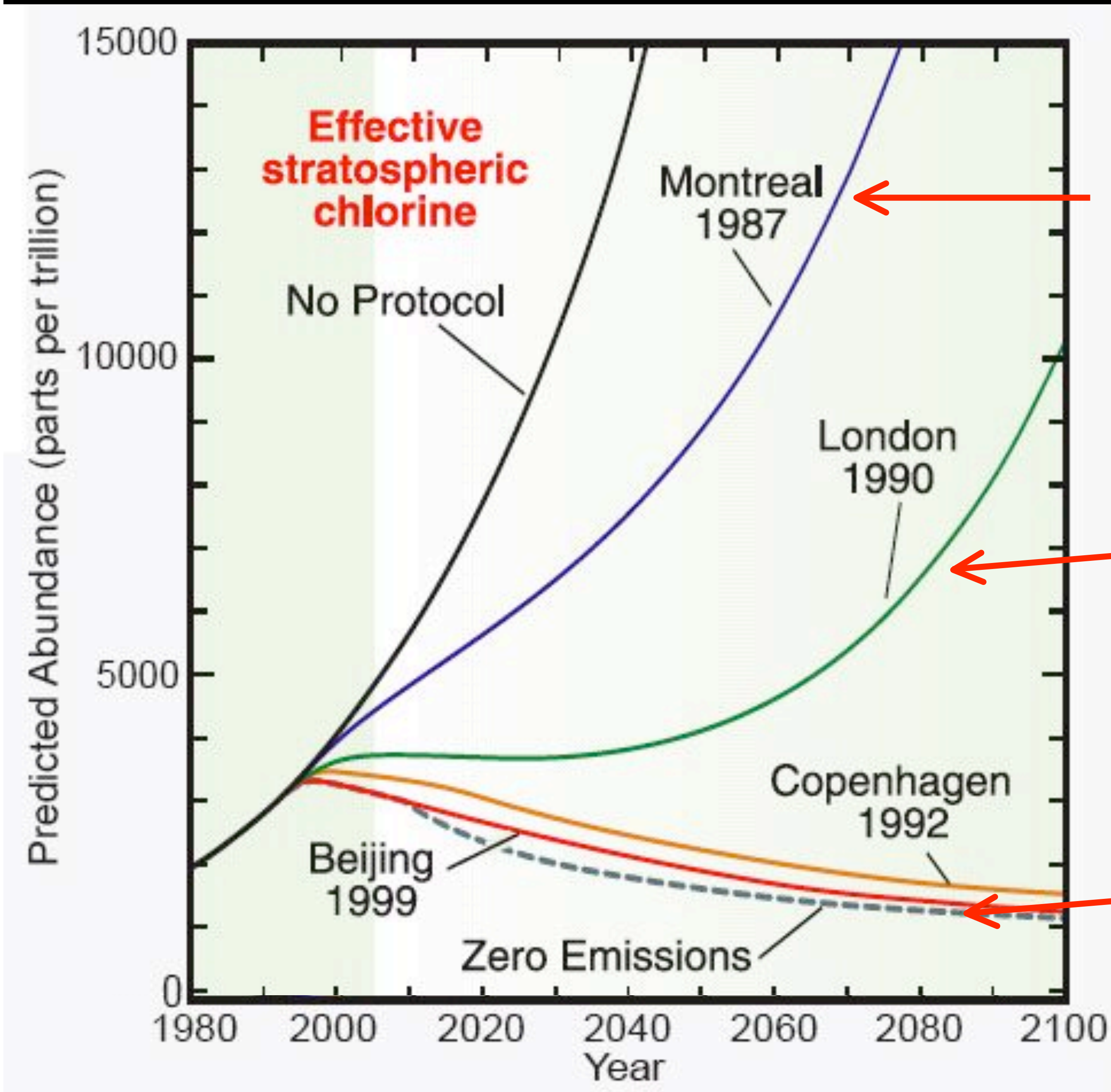


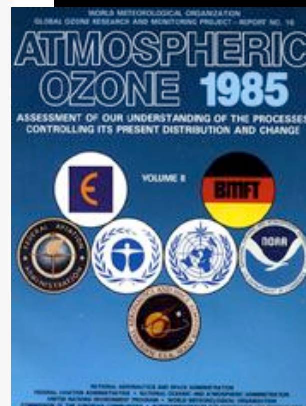


WMO

UNEP

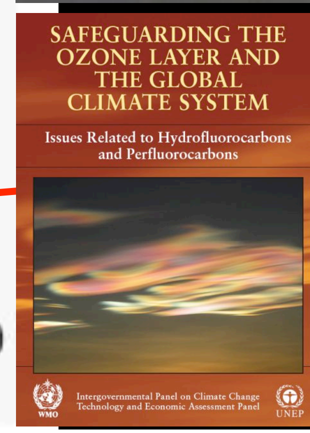
What is an Assessment? Science Input to Key Policy Decisions





Ozone hole discovered

Ozone hole explained; also depletion in mid-lats

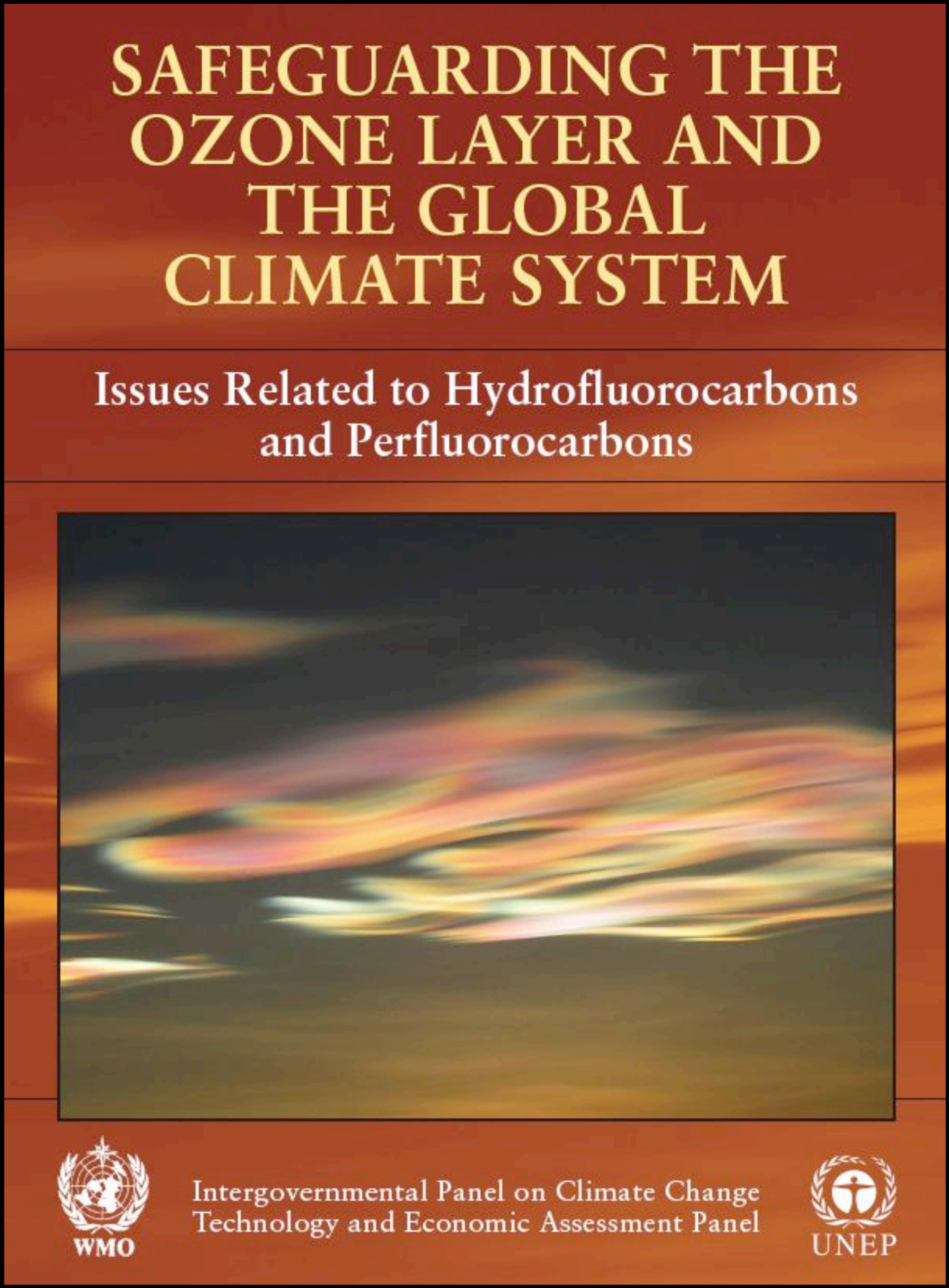


HCFC accelerated phaseout; climate coupling

Elements of a Successful World-Class Assessment

Assessment processes slowly build strength and impact over time (e.g., the 20 years of ozone assessment and ozone policy) through:

- Hard-hitting and policy-relevant science advances
- A strong process of rigorous review, author selection, and approval, stringently followed
- Strong leadership capable of engendering the support and confidence of the science community and of the policy community
- Content that is useful and credible both to the policy community and to the science community
- Clear connection to a policy process



A Surprising Element in The Search for Options: Ozone-Climate Interactions

IPCC (2005)

Solomon, co-chair IPCC WG1

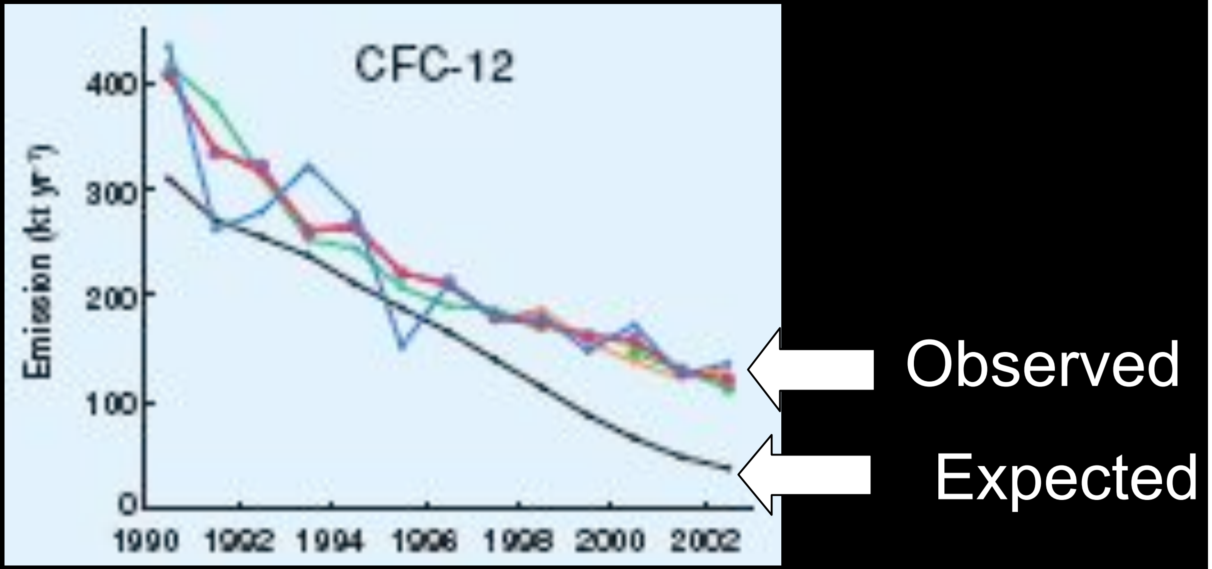
Support by WG1 TSU

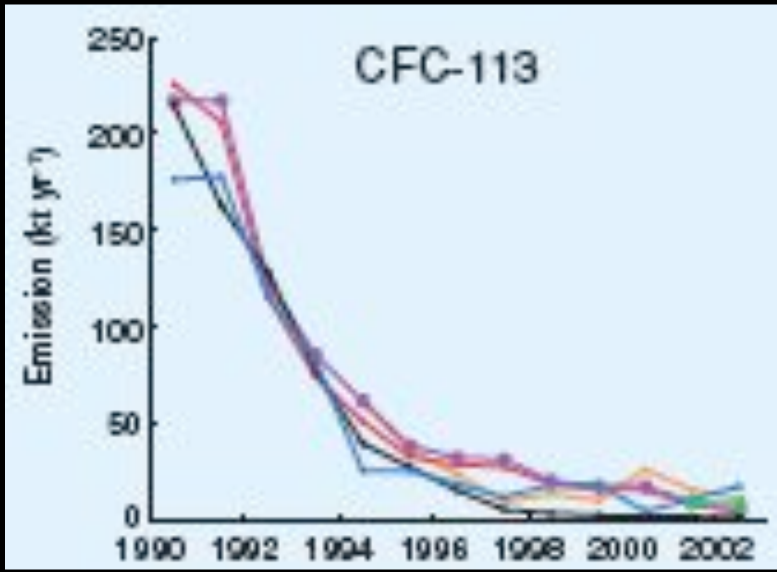
NOAA authors and reviewers

Special Report has shown many win-win solutions

Halocarbon Emissions

- Continuing emissions of CFC-11 and CFC-12 from banks…values in 2002 about a third of the maxima in late 1980s. Why? Banks in existing equipment (refrigeration, AC, foams, etc.)
- Contrast with e.g., CH3CCl3 and CFC-113, where emissions are now <5% of the max. Why? Solvents - so limited banks.





•Current CO_2-equivalent emissions [Table TS-2]:

1.5-1.9 Gt for CFCs

0.53-0.56 Gt for HCFCs

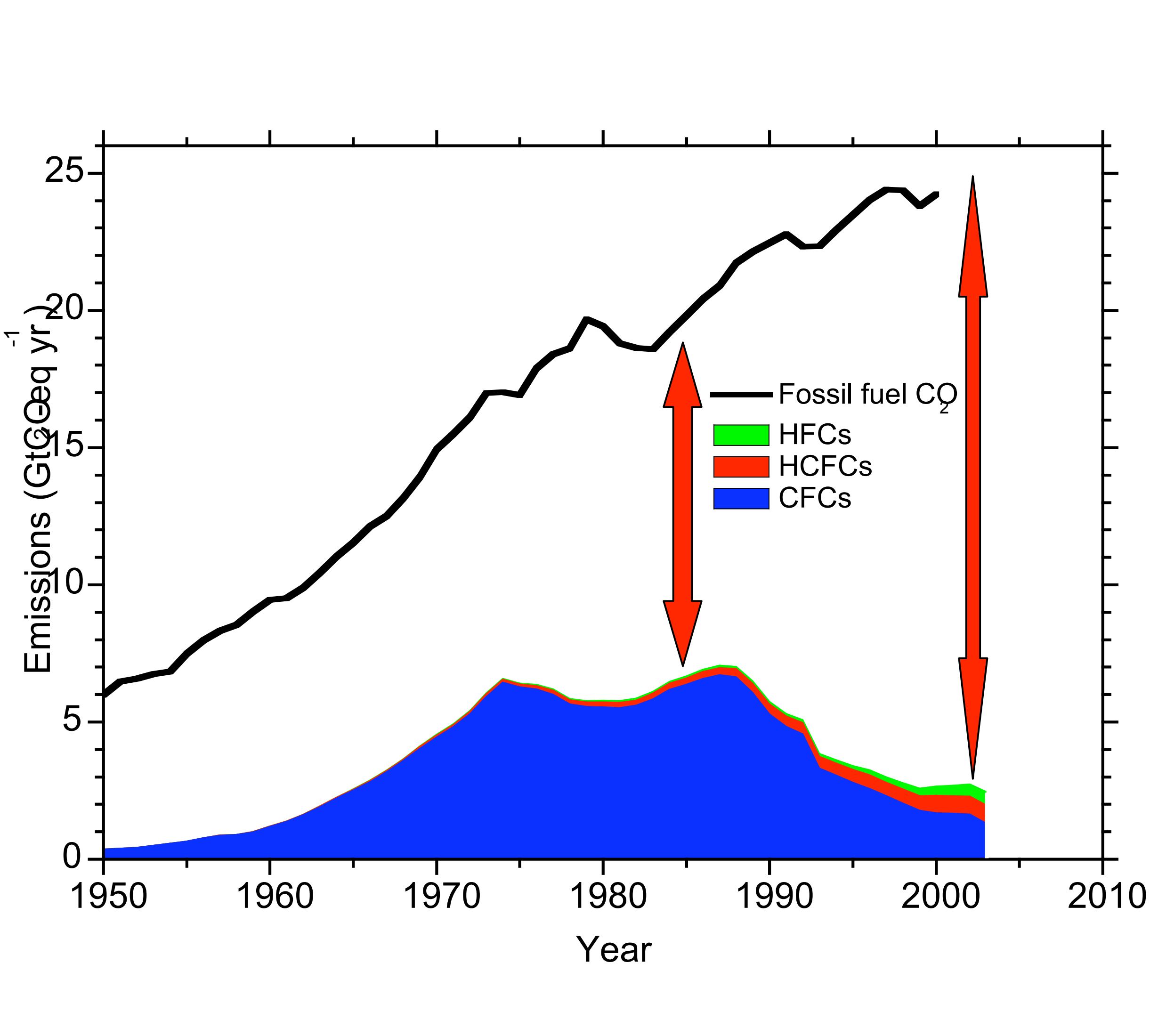
0.36 Gt for HFCs

Halocarbon Emissions

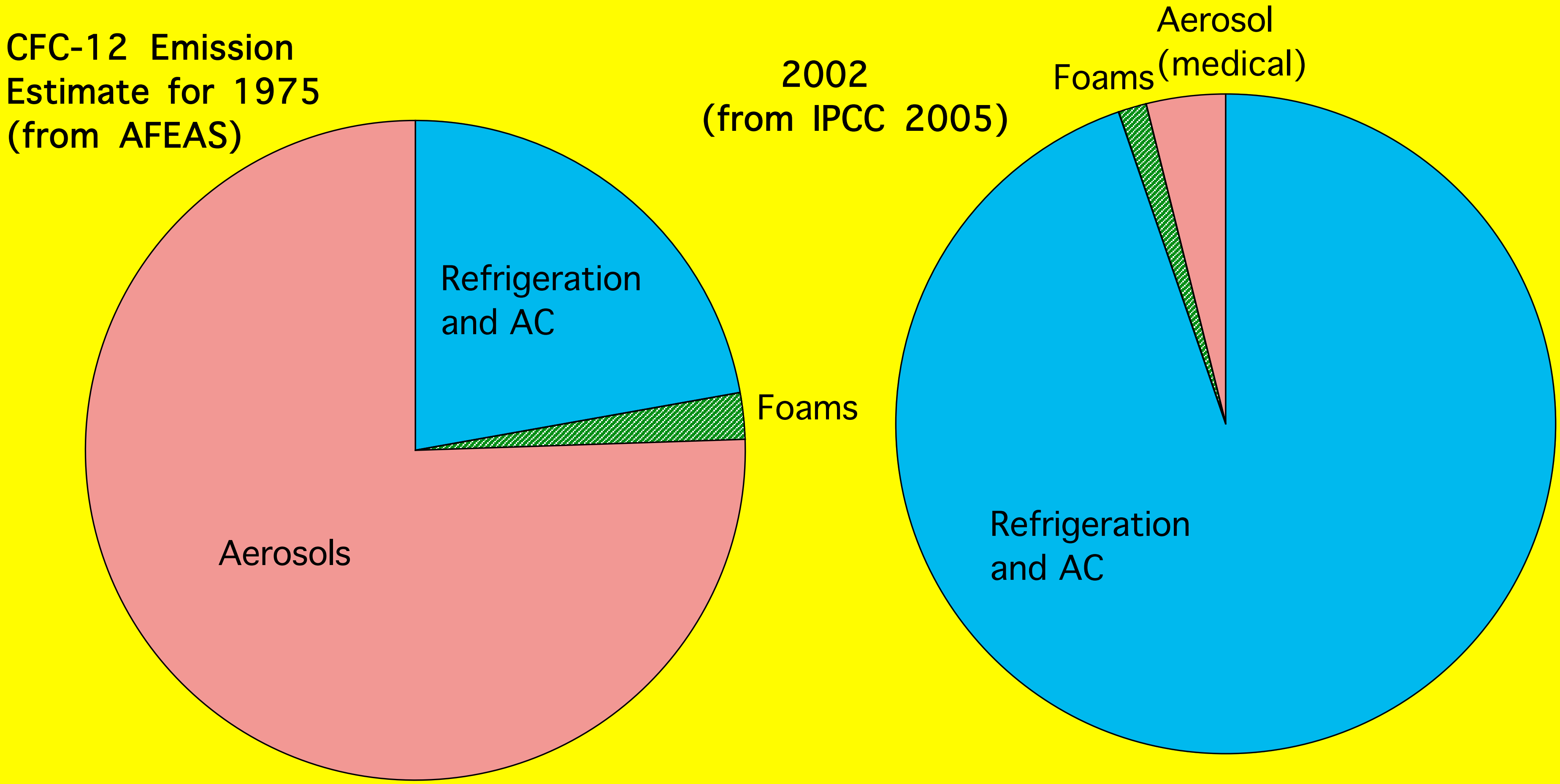
Combined CO_2-equivalent emissions from halocarbons:

~7.5 Gt near 1990, about 33% of that year's CO_2 emissions from global fossil fuel burning

~2.5 Gt near 2000, about 10% of that year's CO_2 emissions from global fossil fuel burning (25 Gt)



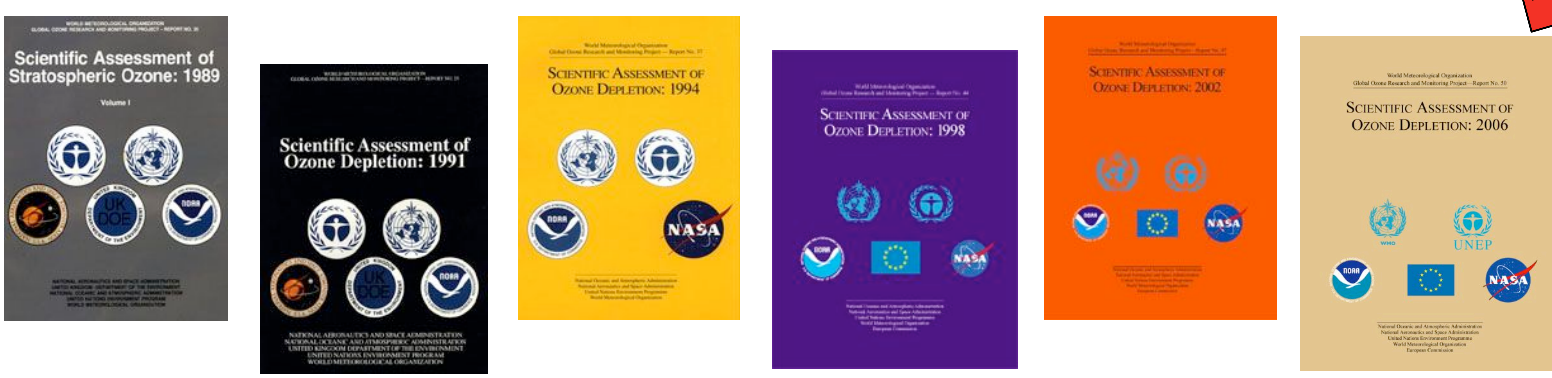
Change in use of CFCs: from 'leaky' to 'tight'



This change implies a large change in the role of banks

The Ozone Science Assessments

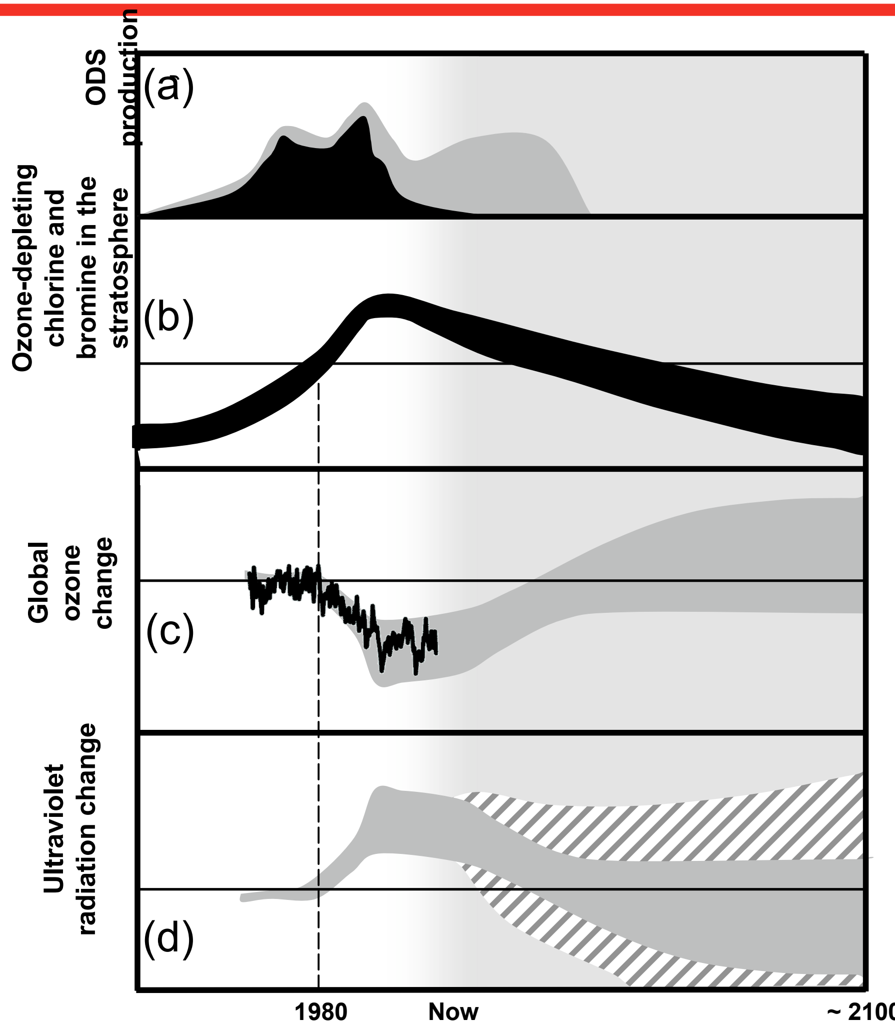
- Worldwide effort involving hundreds of scientists from Article-5 and non-Article 5 countries - as Co-chairs, Lead Authors, Co-authors, Contributors, and Reviewers
- Delivered to the Parties in response to their requests
- Fully reviewed multiple times by the international scientific community
- NOAA has played major roles in all of these reports, which have guided ozone policy decisions.



1989 | 1991 | 1994 | 1998 | 2002 | **2006**

What color will the 2010 volume be?

The Major Findings and Conclusions of the 2006 Science Assessment



ODS production

ODS in the atmosphere

Ozone levels-measured and predicted

UV levels-measured and predicted

The Montreal Protocol is working!

We have entered the "accountability phase" with this issue!

Some Key NOAA Science Inputs

Table 8-2. Direct Global Warming Potentials for selected gases.

Industrial Designation or Common Name	Chemical Formula	Radiative Efficiency [1] ($W\ m^{-2}\ ppbv^{-1}$)	Lifetime (years)	Global Warming Potential for Given Time Horizon: 20 years	100 years	500 years
Carbon dioxide	CO_2	1.41×10^{-5} [2]		1	1	1
Nitrous oxide	N_2O	3.03×10^{-3}	114 [3]	289	298	153
Chlorofluorocarbons						
CFC-11	CCl_3F	0.25	45	6,730	4,750	1,620
CFC-12	CCl_2F_2	0.32	100	10,990	10,890	5,200
CFC-13	$CClF_3$	0.25	640	10,800	14,420	16,430
CFC-113	CCl_2FCClF_2	0.30	85	6,540	6,130	2,690
CFC-114	$CClF_2CClF_2$	0.31	300	8,040	10,040	8,730
CFC-115	$CClF_2CF_3$	0.18	1700	5,310	7,370	9,990
Hydrochlorofluorocarbons						
HCFC-21	$CHCl_2F$	0.14	1.7	530	151	46
HCFC-22	$CHClF_2$	0.20	12.0	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	0.14	1.3	273	77	24
HCFC-124	$CHClFCF_3$	0.22	5.8	2,070	609	185
HCFC-141b	CH_3CCl_2F	0.14	9.3	2,250	725	220
HCFC-142b	CH_3CClF_2	0.20	17.9	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	0.20	1.9	429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	0.32	5.8	2,030	595	181
Hydrofluorocarbons						
HFC-23	CHF_3	0.19 [4]	270	11,990	14,760	12,230
HFC-32	CH_2F_2	0.11 [4]	4.9	2,330	675	205
HFC-41	CH_3F	0.02	2.4	323	92	28
HFC-125	CHF_2CF_3	0.23	29	6,340	3,500	1,100
HFC-134	CHF_2CHF_2	0.18	9.6	3,400	1,100	335
HFC-134a	CH_2FCF_3	0.16 [4]	14.0	3,830	1,430	435
HFC-143	CH_2FCHF_2	0.13	3.5	1,240	353	107
HFC-143a	CH_3CF_3	0.13	52	5,890	4,470	1,590
HFC-152	CH_2FCH_2F	0.09	0.60	187	53	16
HFC-152a	CH_3CHF_2	0.09	1.4	437	124	38
HFC-227ea	CF_3CHFCF_3	0.26 [4]	34.2	5,310	3,220	1,040
HFC-236cb	$CH_2FCF_2CF_3$	0.23	13.6	3,630	1,340	407
HFC-236ea	CHF_2CHFCF_3	0.30	10.7	4,090	1,370	418
HFC-236fa	$CF_3CH_2CF_3$	0.28	240	8,100	9,810	7,660
HFC-245ca	$CH_2FCF_2CHF_2$	0.23	6.2	2,340	693	211
HFC-245fa	$CHF_2CH_2CF_3$	0.28	7.6	3,380	1,030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	0.21	8.6	2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	0.40	15.9	4,140	1,640	499
Chlorocarbons						
Methyl chloroform	CH_3CCl_3	0.06	5.0	506	146	45
Carbon tetrachloride	CCl_4	0.13	26	2,700	1,400	435
Methyl chloride	CH_3Cl	0.01	1.0	45	13	4

Table 8-6. Comparison of scenarios and hypothetical cases [a]: the year when EESC drops below the 1980 value for both midlatitude and polar vortex cases, and integrated EESC differences (midlatitude case) relative to the baseline (A1) scenario. Note that the polar recovery times have not been given in previous Assessments; interpretation of any comparison between these numbers and recovery times given in previous Assessments requires an understanding of the large role played by the different transport times from the troposphere to the stratospheric midlatitude and polar vortex regions.

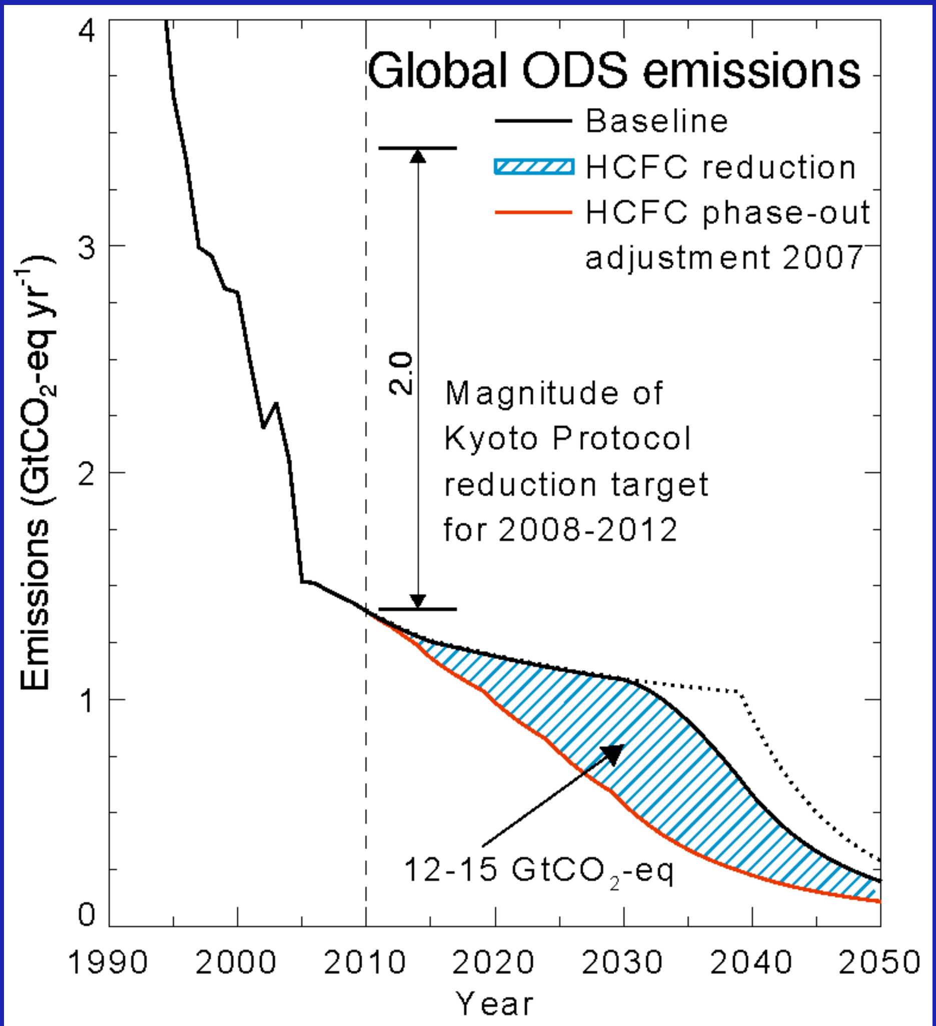
Scenario and Cases	Percent Difference in integrated EESC relative to baseline scenario for the midlatitude case: $\int_{1980}^{x} EESC\,dt$ (Midlatitude)	$\int_{2007}^{x} EESC\,dt$ (Midlatitude)	Year (x) when EESC is expected to drop below 1980 value: Midlatitude	Antarctic vortex [b]
Scenarios				
A1: Baseline scenario			2048.9	2065.1
Cases [a] of zero production from 2007 onward of:				
P0: All ODSs	−8.0	−17.1	2043.1	2060.3
CFCs	−0.1	−0.3	2048.8	2065.0
Halons	−0.2	−0.5	2048.8	2065.1
HCFCs	−5.5	−11.8	2044.4	2062.2
Anthropogenic CH_3Br	−2.4	−5.1	2047.9	2063.7
Cases [a] of zero emissions from 2007 onward of:				
E0: All ODSs	−19.4	−41.7	2034.0	2049.9
CFCs	−5.3	−11.5	2045.0	2060.3
CH_3CCl_3	−0.1	−0.2	2048.9	2065.1
Halons	−6.7	−14.4	2045.6	2061.9
HCFCs	−7.3	−15.7	2043.7	2061.8
CCl_4	−1.3	−2.9	2048.5	2064.9
Anthropogenic CH_3Br	−2.4	−5.1	2047.9	2063.7
Cases [a] of full recovery of the 2007 banks of:				
B0: All ODS	−12.9	−27.8	2040.8	2056.7
CFCs	−5.2	−11.3	2045.1	2060.4
Halons	−6.7	−14.3	2045.7	2062.0
HCFCs	−1.9	−4.1	2048.4	2064.8
CH_3Br sensitivity:				
Same as A1, but CH_3Br anthropogenic emissions set to 20% in 1992 [c]	3.1	6.6	2050.6	2067.7
Same as A1, but zero QPS production from 2015 onward	−1.5	−3.2	2047.9	2063.7
Same as A1, but critical-use exemptions continued at 2006 level	1.9	4.0-4.7	2050.1	2067.0

[a] Importance of ozone-depleting substances for future EESC were calculated in the hypothetical "cases" by setting production or emission to zero in 2007 and subsequent years or the bank of the ODS to zero in the year 2007 alone. These cases are not mutually exclusive, and separate effects of elimination of production, emissions, and banks are not additive.

[b] This metric specifically for Antarctic polar vortex ozone depletion has not been shown in any previous ozone Assessment.

[c] In the baseline scenario, this fraction was assumed to be 30% in 1992, with a corresponding emission fraction of 0.88 of production. In this alternative scenario, an anthropogenic fraction was assumed to be 20%, with an emission fraction of 0.56 of production. In both scenarios, the total historic emission was derived from atmospheric observations and a lifetime of 0.7 years.

Montreal Sep 2007 adjustment: HCFC early phase-out



Reduction in emissions:

- HCFCs 'transition' speedup. A tangible step in both ozone and climate policy.
- 12-15 $GtCO_2$-eq potential reduction, which is significant (compare to 2 Gt annual reductions globally under Kyoto).
- Realizing this potential depends on technology and science: needs development and testing of new, improved substitute chemicals (e.g., molecules like 2,3,3,3-tetrafluoropropene (CF3CF=CH2), proposed for mobile air conditioning units). NOAA has long been leaders in testing of new compounds (Ravi et al.)

Looking Ahead: The 2010 Ozone Science Assessment

Co-Chairs: A. R. Ravishankara, J. A. Pyle, P. Newman, Ayité-Lô Ajavon

The <u>Terms of Reference</u> from the Parties TBD,but expect elements of the following at least:

- **Assess ozone's impact on climate change**

- **Assess how much benefit to the ozone layer and the climate is obtained by the early HCFC phaseout**

….

Key Technical Support: Christine A. Ennis, NOAA/ESRL CSD

NOAA leadership of the process, and many NOAA contributions to the above science topics are 'virtually certain'.

20 Years of IPCC WG1 Comprehensive Assessments

Governments require information on climate change for negotiations

The IPCC formed in 1988 under auspices of the United Nations

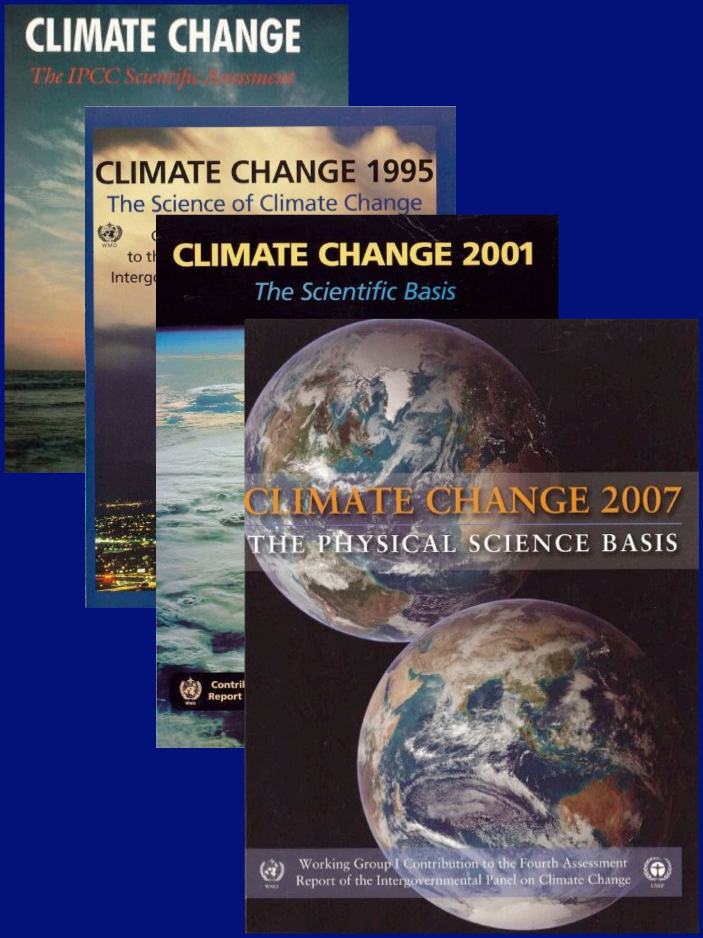
Function is to provide assessments of the science of climate change as input to the United Nations Framework Convention on Climate Change (UNFCCC)

Substance and leadership of IPCC WG1 reports in the hands of scientists

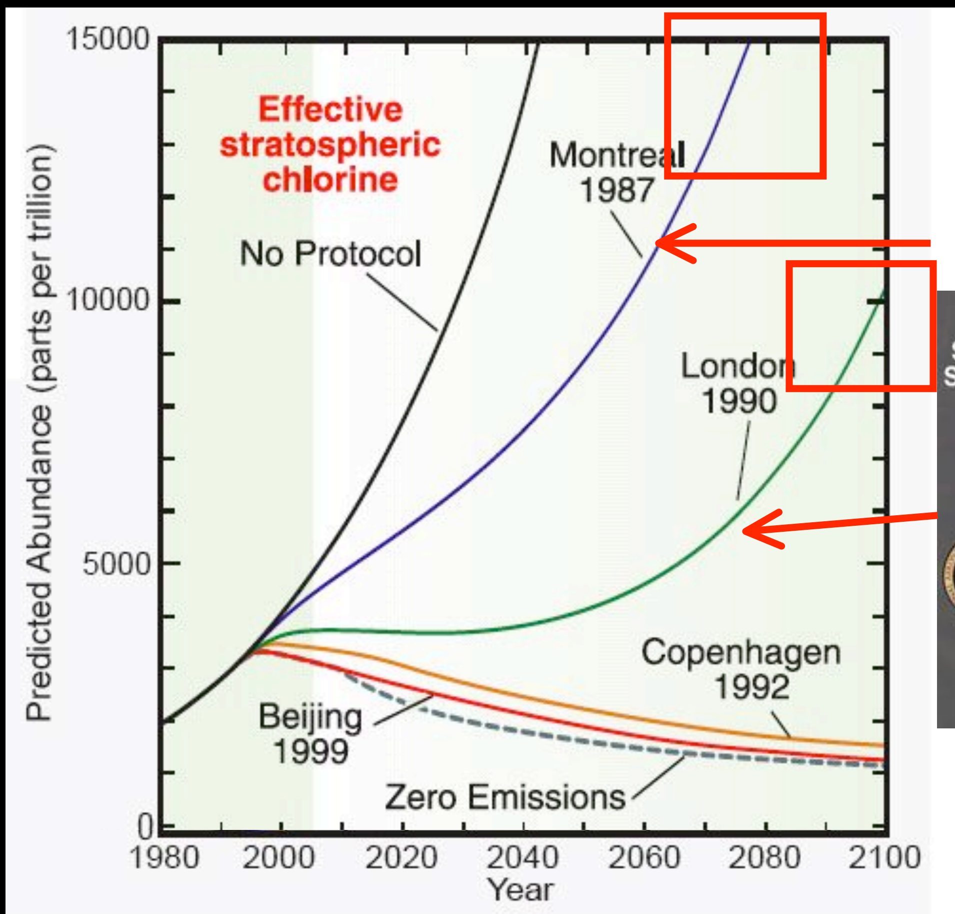
Input to actions in Rio de Janeiro and Kyoto

Acceptance of science foundation in Bali - a starting point on a long road ahead

Next IPCC assessment? TBD, discussion in Budapest, April, 2007



Are Future Science Assessments Needed for Climate Policy, As In Ozone Policy?



Ozone hole discovered

Ozone hole explained; also depletion in mid-lats

Currently, Kyoto implies less global (all countries) emission reduction than the original Montreal agreement in 1987.

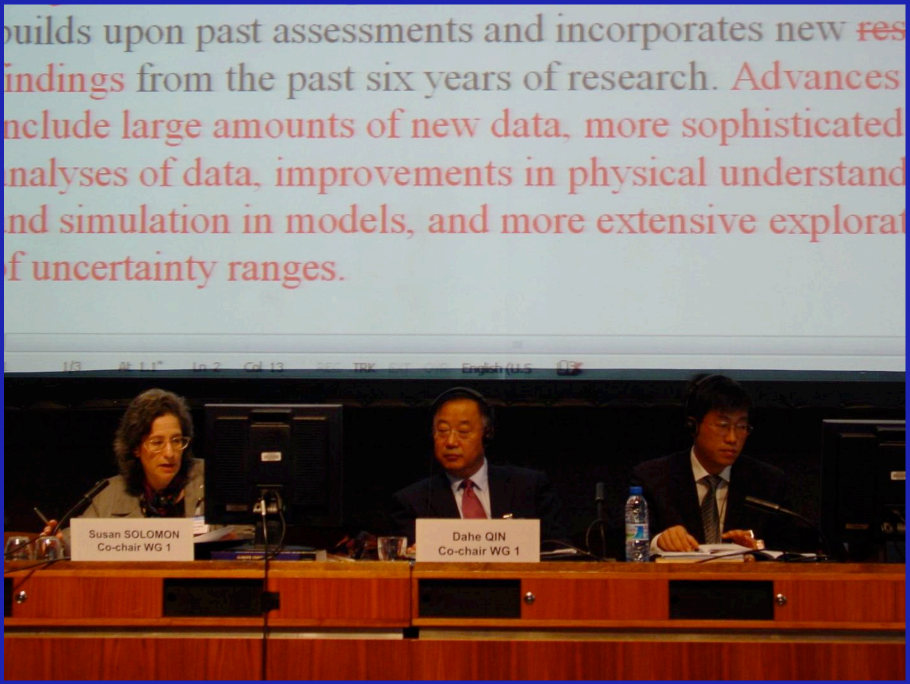
What is needed regarding climate science and assessment to inform e.g. possible future 50-80% emission reductions?

Preparation and Review of the IPCC WG1 AR4

- Each report is an assessment of the state of understanding based upon peer-reviewed published work. IPCC assesses published research but does not do research.

- Each assessment goes through multiple reviews and revision and re-review over a period of years.

- Informal draft prepared, comments sought from 6-12 outside experts for each chapter (Oct 2004 - Mar 2005). Formal first order draft (FOD) reviewed by about 600 reviewers worldwide (Sept -Nov 2005). Formal second order draft (SOD) re-reviewed by about 600 experts worldwide and by dozens of governments (April-May 2006). Govt comments on revised Summary for Policy Makers (Oct-Nov 2006). WG1 received and considered over 30000 comments in total.



- Summary for Policy Makers approved word-by-word by 113 govts in Paris in Feb, 2007. Provides a unique set of robust findings agreed by all governments.

- Co-chairs: Solomon and Qin

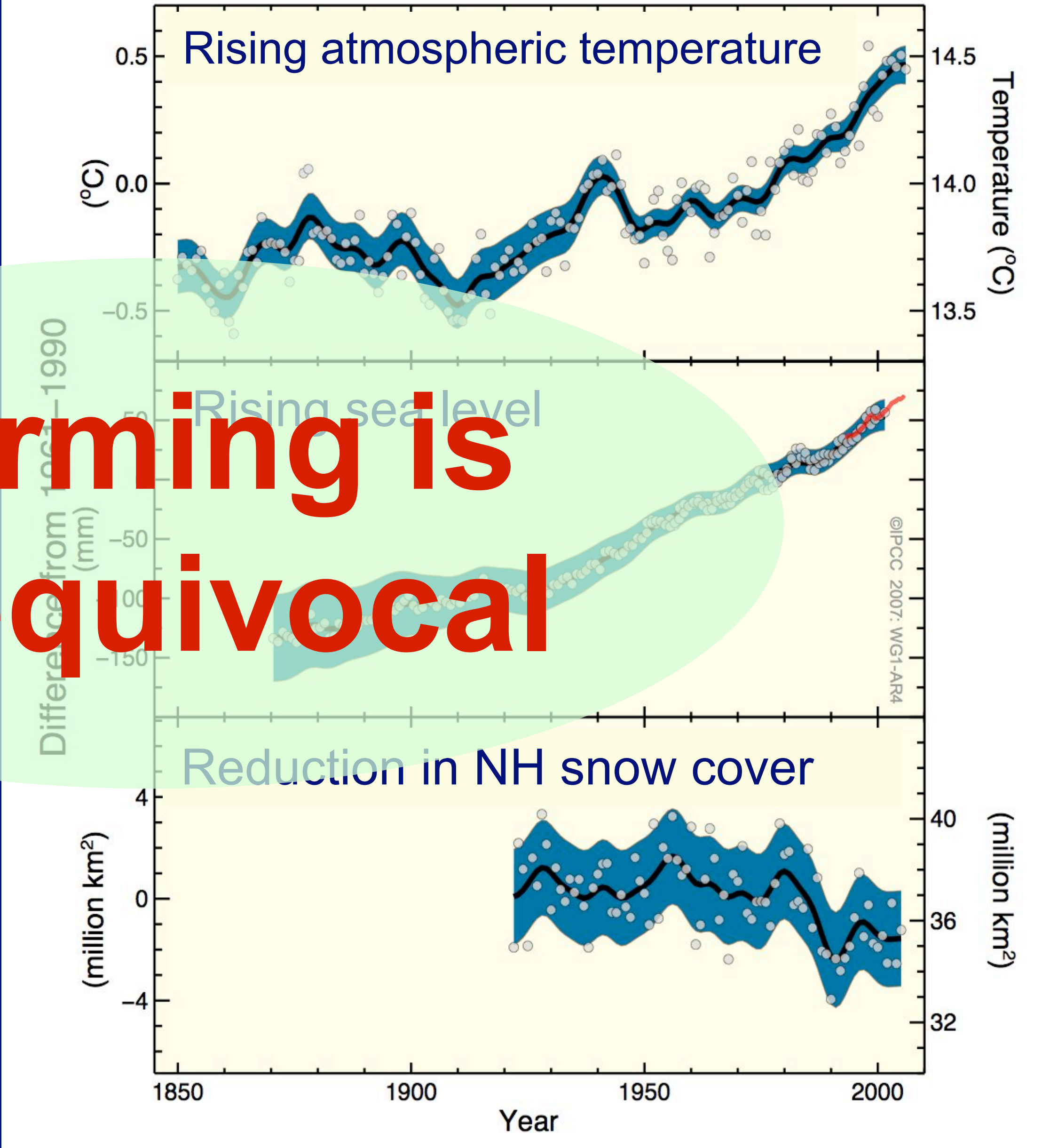
- Technical Support: IPCC WG1 Technical Support Unit (Manning, Marquis, Averyt, Tignor, Miller)

- Many NOAA authors and reviewers
- Bringing the discipline of science to policy

Many Changes Signal A Warming World

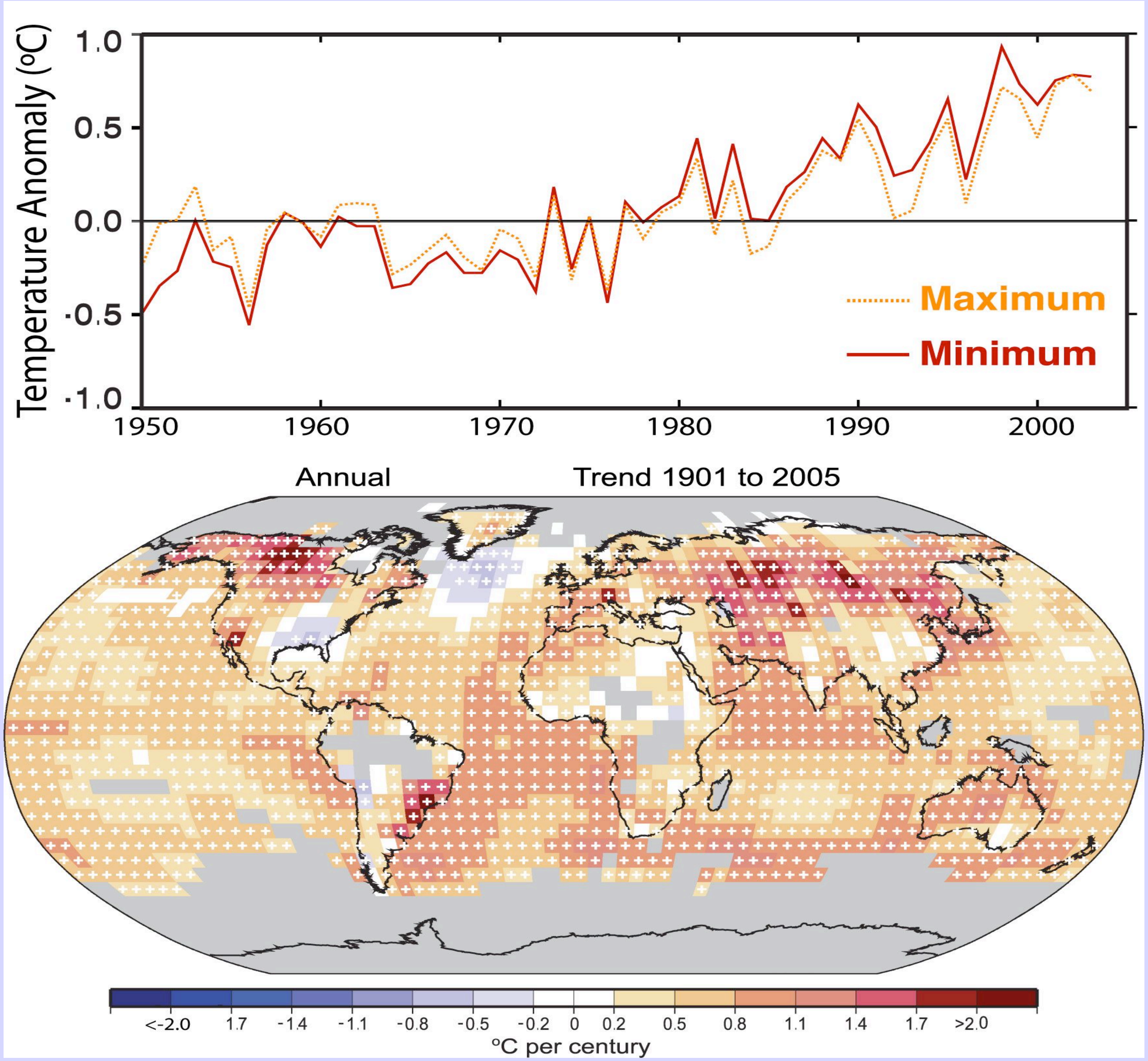
And……

- Atmospheric water vapor increasing
- Glaciers retreating
- Arctic sea ice extent decreasing
- Extreme temperatures increasing
- …………

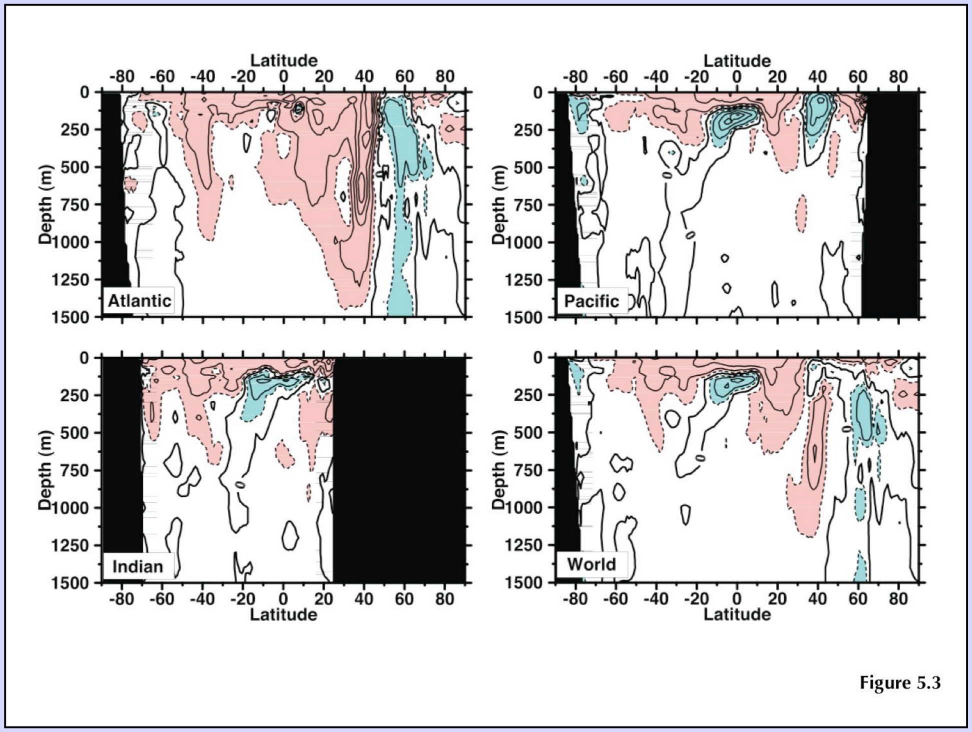


Warming is Unequivocal

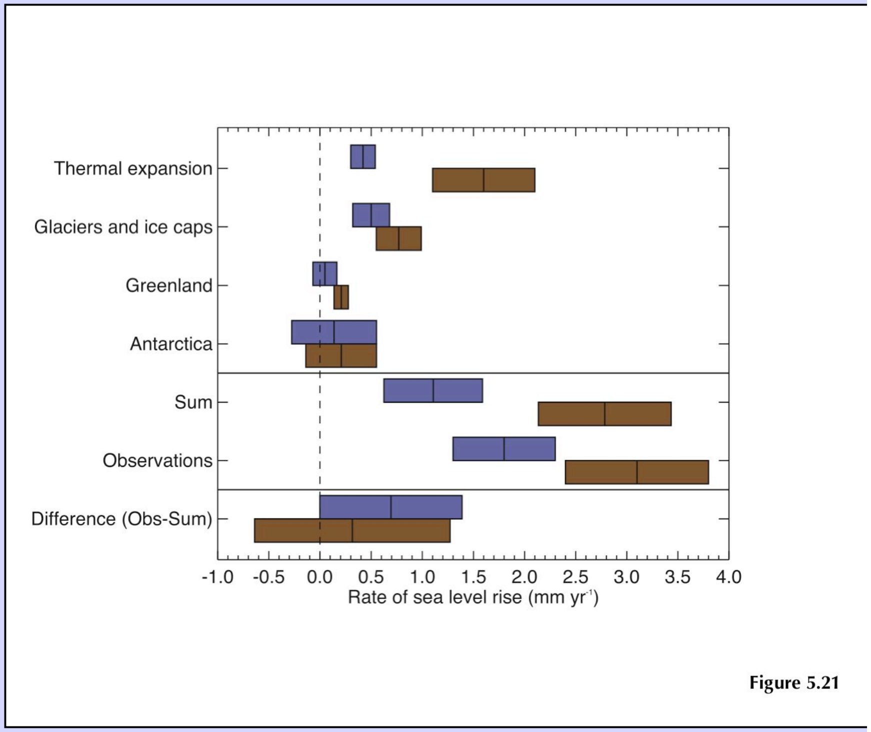
Change in Annual Temperatures *(Karl et al.)*



Change in Ocean Temperatures and SLR Contributions *(Levitus et al.)*



Linear trend (1955–2003) of zonally averaged temperature in the upper 1,500 m of the water column of the Atlantic, Pacific, Indian and World Oceans.



Estimated contributions to SLR:

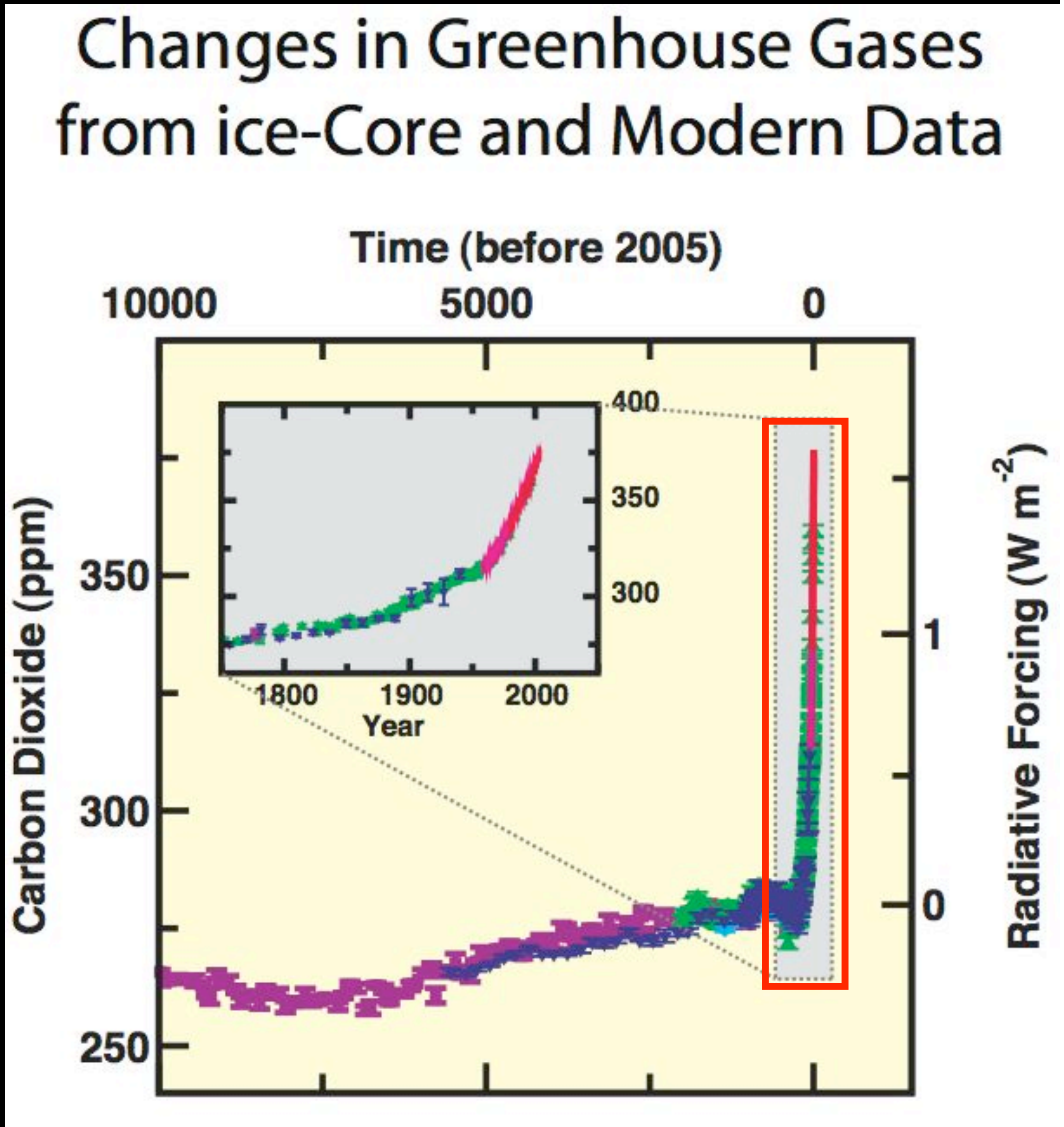
1961 to 2003 (blue) and 1993 to 2003 (brown).

The warming ocean has been expanding in volume leading to a sea level rise contribution of about 0.4 mm/year. Thermal expansion and melt of small glaciers and ice caps are estimated to be the dominant contributions to SLR.

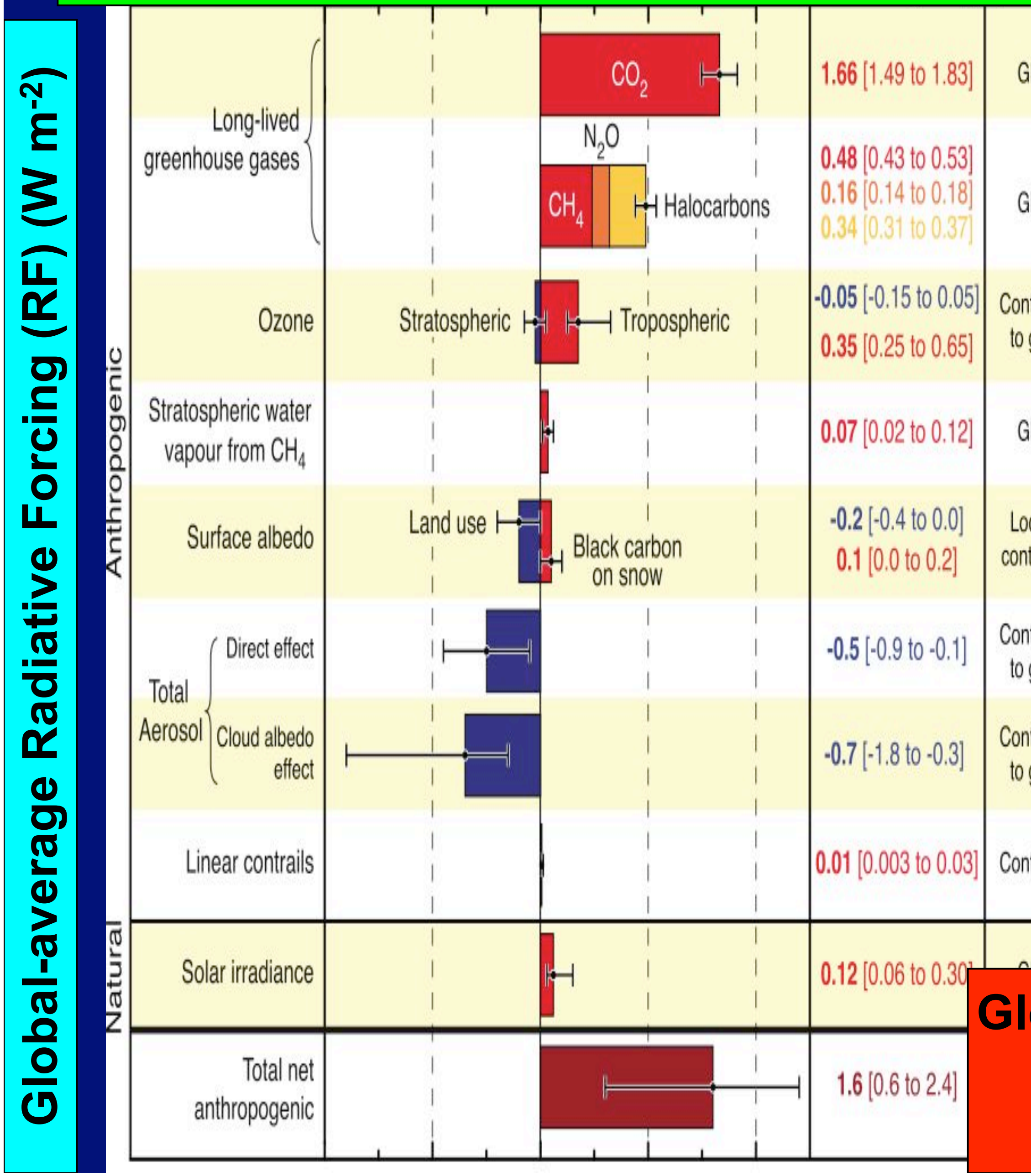
Human and Natural Drivers of Climate Change: Unprecedented [IPCC, 2007]

• Dramatic rise of CO_2 in the industrial era, changing the energy budget, and 'forcing' the climate in a new way not experienced in many thousands of years.

Major contributions by Tans and colleagues



The Range of Drivers of Climate Change [1750 to Present-day]



Seminal NOAA contributions include:

Key observations and interpretation of CO_2, N_2O, CH_4, halocarbons, strat and trop ozone, aircraft, stratospheric water, and aerosol forcings.

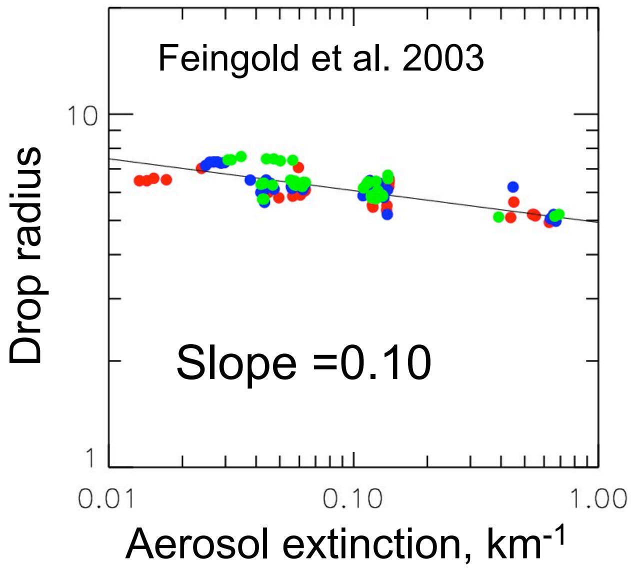
Also: Lab and modelling of RT, lifetimes, GWPs.

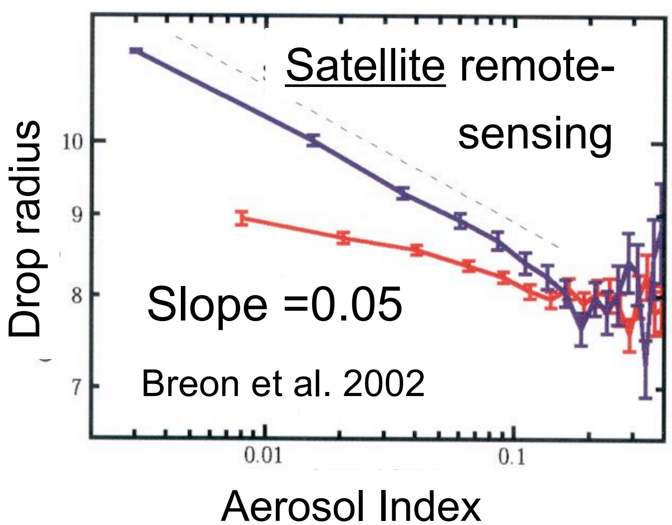
And more…

Global-mean Anthro RF positive
➔Warming influence
[*very high confidence*]

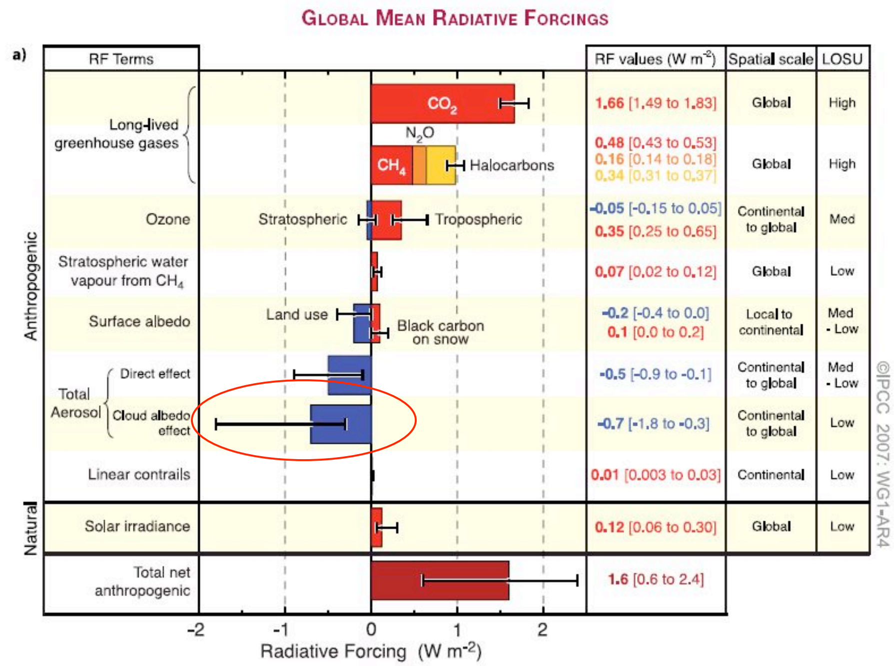
Measurements of Aerosol-Cloud Interactions: Implications for the Aerosol First Indirect Effect

Surface remote-sensing





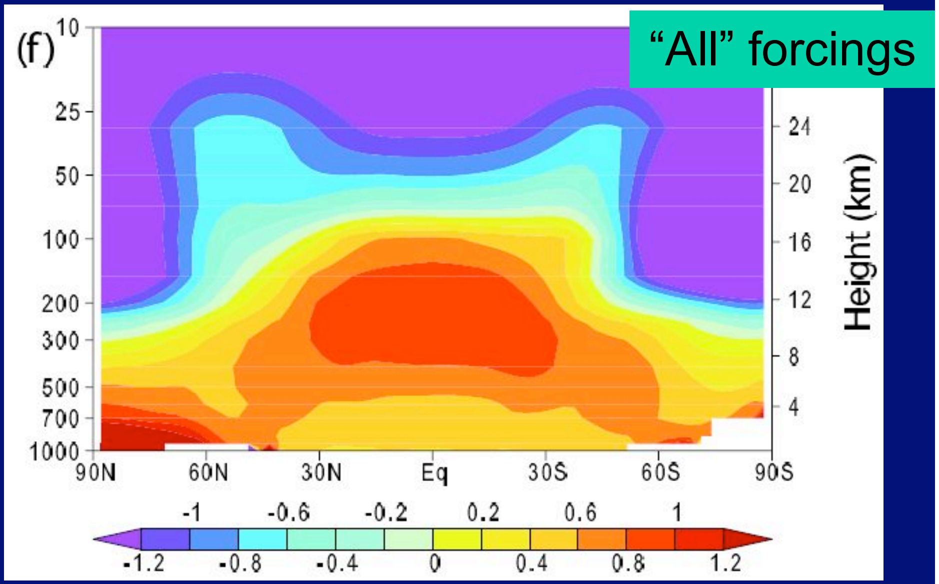
Slope determined by:
aerosol number conc., size/composition
cloud turbulence, etc.



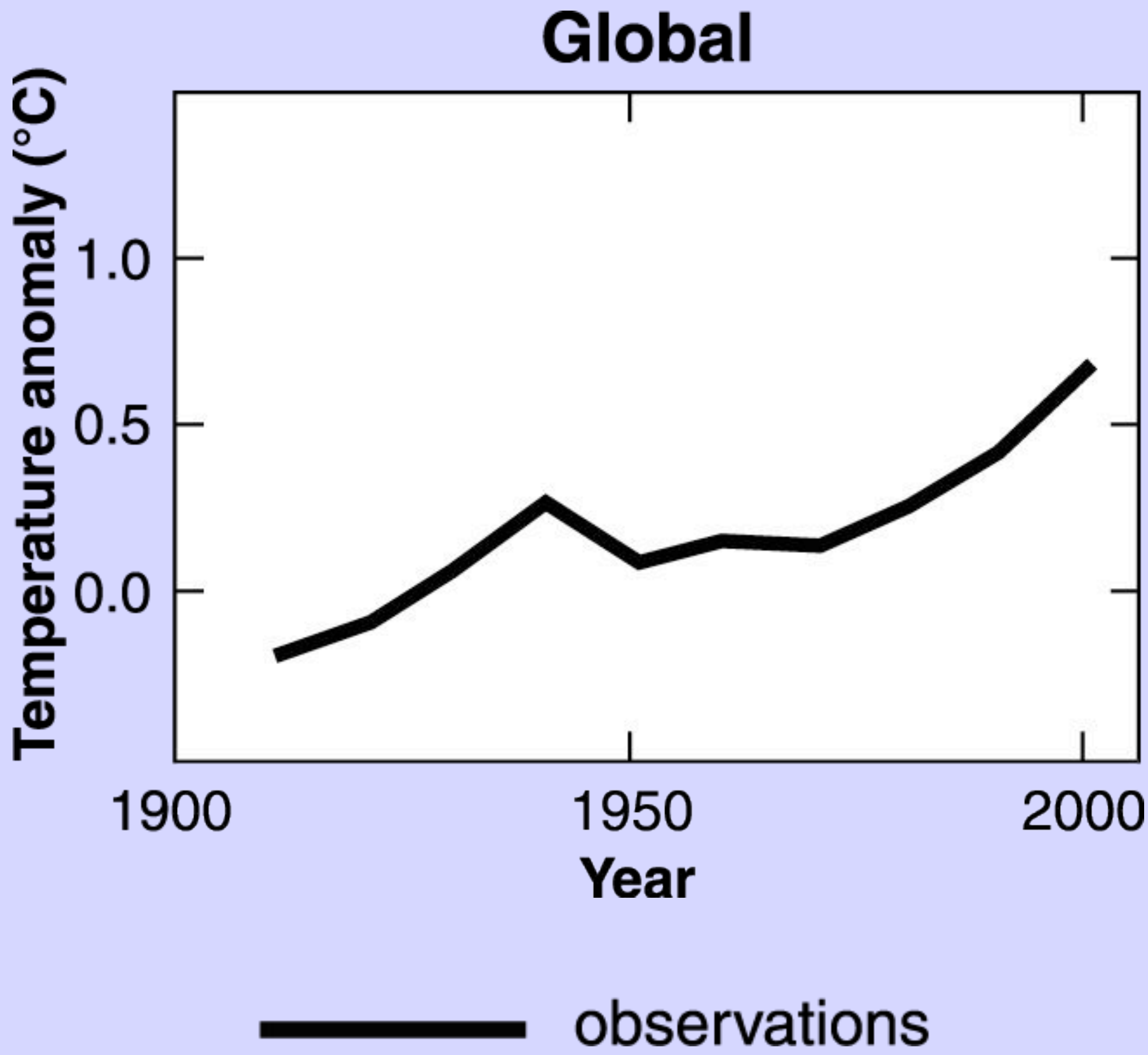
Estimate of the aerosol first indirect effect in the AR4 considered surface as well as satellite-derived slope of drop radius-aerosol relationship

Attribution and Patterns of Forcing

- Attribution is linked to time-space patterns of responses to the array of forcings (e.g, aerosol effect on NH/SH ratio, ozone effect on stratosphere/troposphere ratio….)
- Simulation of the observed pattern and relationship to forcings in space and time (including stratospheric ozone, tropospheric ozone, aerosols, volcanoes, etc.) is key to the success of climate attribution.
- NOAA science has helped to bring together information on forcings, their spatial patterns, radiative forcing, feedbacks, and model responses.



Are Humans Responsible?



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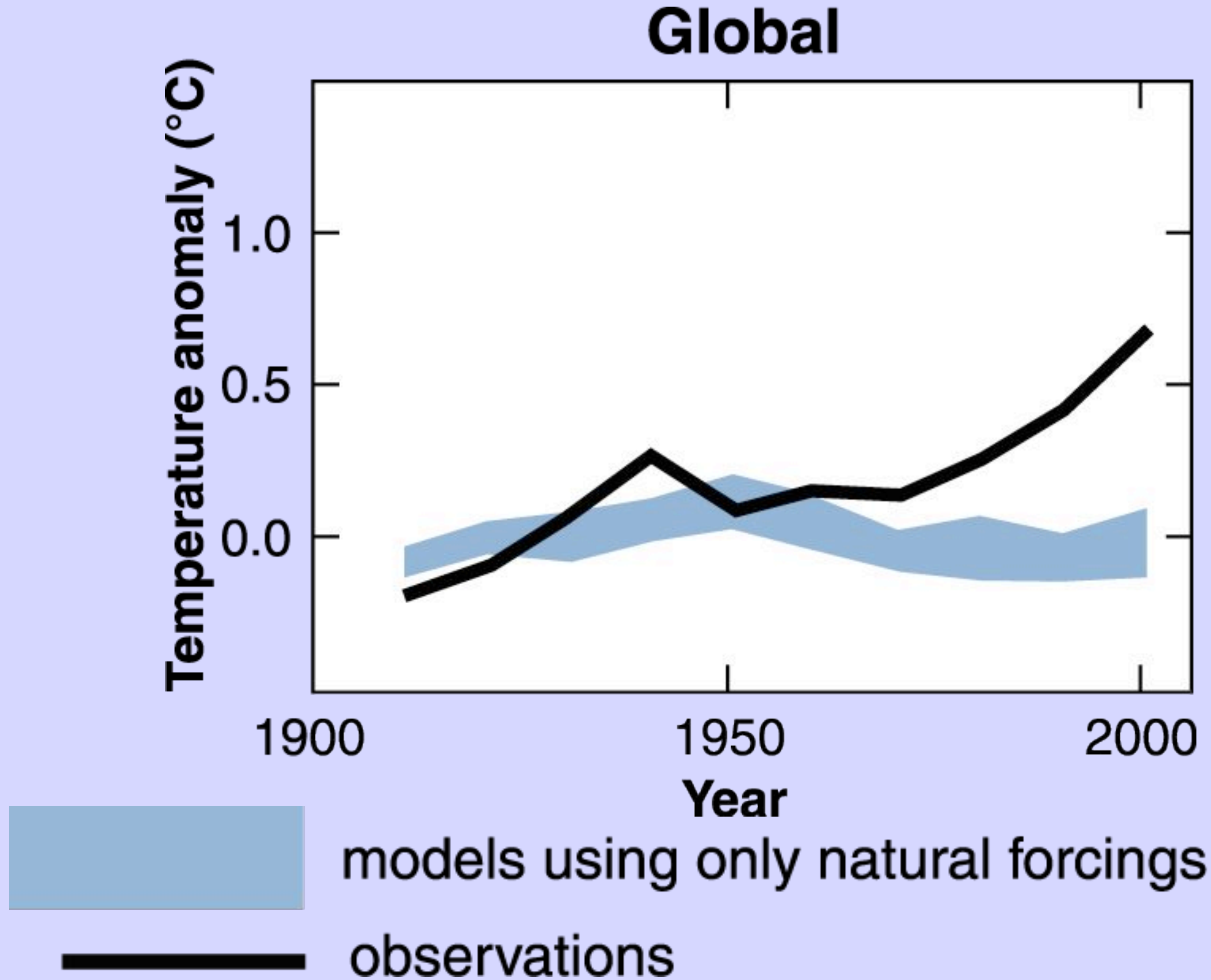
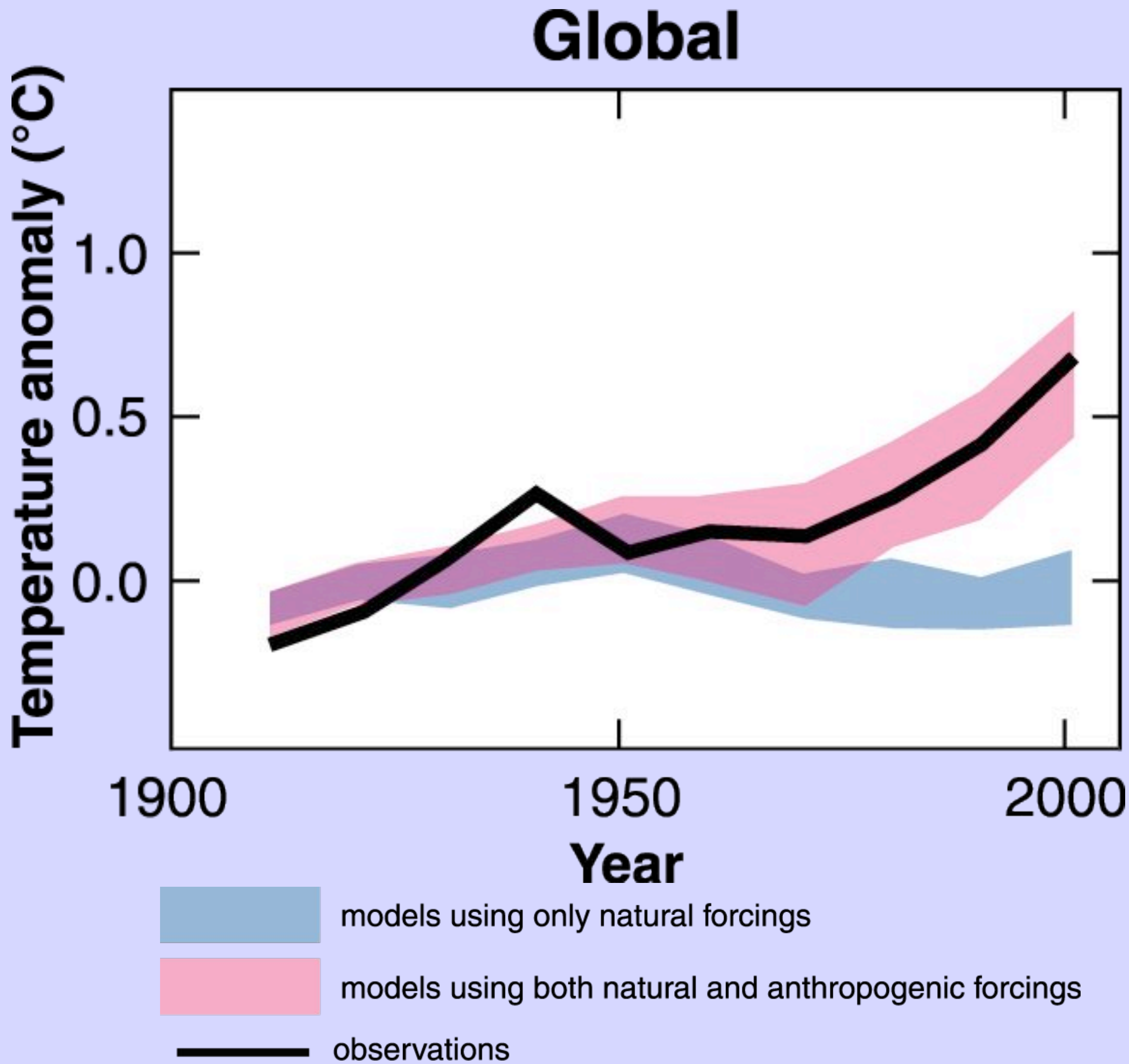


Are Humans Responsible?

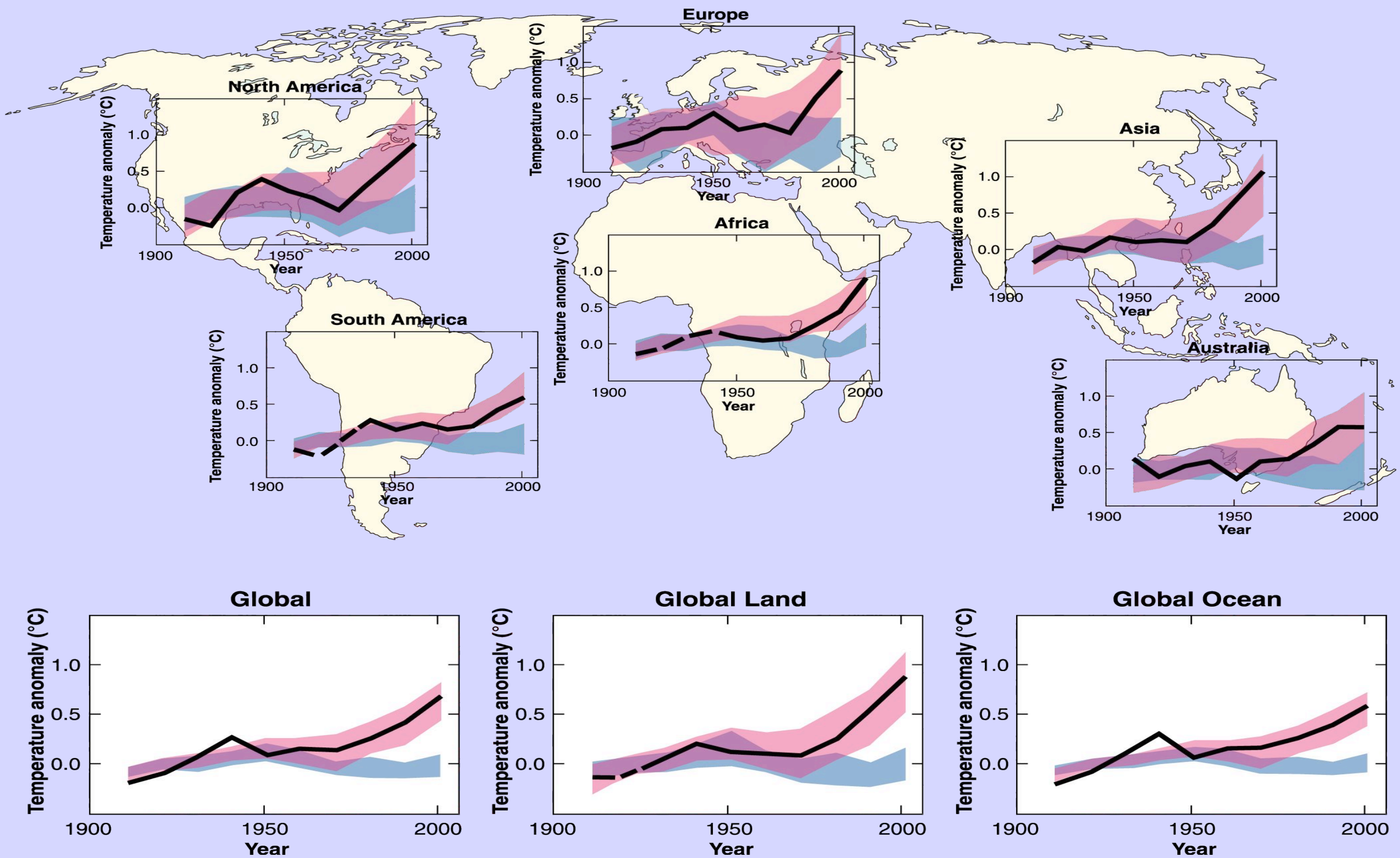
IPCC (1995):
"Balance of evidence suggests discernible human influence"

IPCC (2001):
"Most of warming of past 50 years *likely* (odds 2 out of 3) due to human activities"

IPCC (2007):
"Most of warming *very likely* (odds 9 out of 10) due to greenhouse gases"



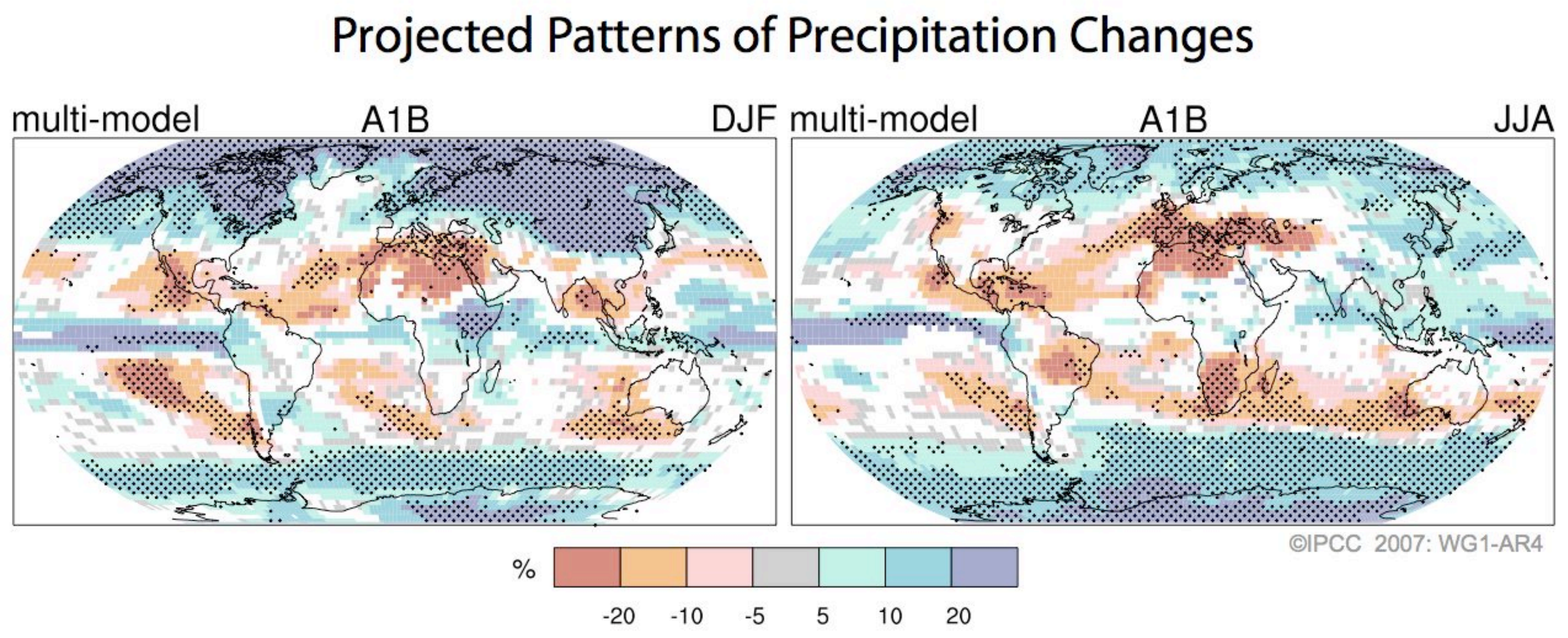
Continental Attribution



Continental scale warming is *likely* (2 out of 3 odds) due to increases in anthropogenic greenhouse gases

Future: More regional -> more info on forcings, feedbacks, and responses in <u>space and time</u> essential

Projections of Future Changes in Climate



New in AR4: Rainfall in the SPM at a new level of prominence. Projected drying in much of the subtropics, more rain in higher latitudes, continuing the broad pattern of rainfall changes already observed. Major contributions from GFDL (work of Held, Stouffer, Ramaswamy et al.).

Future: Understand relationships of rainfall, heat waves, sea ice…..to GHG, ozone, aerosols...the forcing/attribution/projection challenge is just beginning. Many opportunities/needs for NOAA science and assessments.

Summary and Outlook

- NOAA has played a key role in shaping science assessments, and the assessments in turn have shaped our work and ourselves.

- NOAA has heritage and leadership in international and national science assessment processes: how to do the challenging task of science assessment that affects public policy

- NOAA science inputs have been major for both ozone depletion and climate change.   NOAA has taken an 'end-to-end' approach in its approach to both science and assessment on ozone and climate.

- NOAA is well placed to continue to make major contributions to future science and assessments needed to inform policy decisions in the 21st century.

Similar Time Line of a WG1 AR5 as the WG1 AR4?

Fall 2008	Election of chair, WG co-chairs, bureau
early 2009	One or two scoping meetings
Nov 2009	Panel approval of outlines for reports
Apr 2010	Author teams selected by WGI Bureau
Sep 2010	Lead Author meeting 1
Jan 2011	Zero order draft complete
May 2011	Lead Author meeting 2
Aug 2011	First draft complete
Dec 2011	Lead Author meeting 3
Feb 2012	Second draft complete
Jun 2012	Lead Author meeting 4
Jan 2013	WGI panel approves SPM and accepts report

Scenarios

Model runs and archive